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Interpretation of the fetal ECG during labor: the effect of uterine contractions

Israel Thaler[1], Ilan E. Timor[1], and Itschak Goldberg[2]

[1]Department of Obstetrics & Gynecology "A", Rambam Medical Center, and [2]Faculty of Electrical Engineering, Technicon, Israel Institute of Technology, Haifa, Israel

1 Introduction

Analysis of the fetal electrocardiogram (FECG) during labor has received relatively little attention in the past [2, 4, 14]. More recently computer-based systems have been employed to enhance the fetal ECG, but the patterns obtained were inconsistent and sometimes contradictory [7, 10, 11, 16]. In the earlier computer-based systems, signal enhancement for providing a good signal-to-noise ratio, distorted the low frequency components of the P and ST waveforms [10]. The latter components were subsequently shown to be the best indicators of fetal condition. Consequently, only systems which retain and enhance these ECG components appear to be valid for establishing their clinical value. In this study we employed a computer based system to investigate the fetal ECG during and between contractions, in the active state of the normal labor.

Curriculum vitae

ISRAEL THALER, *born 1945, graduated from the Hadassah Medical School – the Hebrew University in Jerusalem in 1973. Training in Obstetrics and Gynecology at the Rambam Medical Center, in Haifa. Research Fellow at the Nuffield Institute of Medical Research, Oxford (Prof.* G. S. DAWES*), 1977–1978. At present Director of Maternal-fetal Medicine, Rambam Medical Center. Research in the field of perinatal physiology, including computer analysis of fetal heart rate, fetal ECG and EEG signals and doppler blood flow measurements in the fetus and mother. Also special interests in hypertension of pregnancy erythroblastosis and computer applications of perinatal databases.*

2 Patients and methods

Twenty five patients with a low risk pregnancy, who were admitted to the delivery suit between 38–41 weeks gestation, participated in the study. All patients were non smokers and received no medications prior to or during the recordings. All the recordings were made during the active stage of labor after rupture of the membranes with the patients in a left lateral positions. The FECG signal was obtained from a conventional stainless steel spiral scalp electrode and the intrauterine pressure was measured using a fluid filled flexible polythene catheter. Both fetal heart rate (FHR) and intrauterine pressure were continuously displayed on an HP8040 fetal monitor. The fetal ECG signal was amplified (bandpass: 0.5–300 Hz) through a Gould universal amplifier (model 4615–55). The FECG and intrauterine pressure signals were then simultaneously recorded on a Teac R610 FM data recorder and subsequently sampled at 1KHz through a 12 bit analog to digital converter into a micro PDP computer (Digital Equipment Corporation).

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2.1 Signal processing

The fetal ECG is averaged over a predetermined period in order to remove noise interference. The noise arises from such sources as fetal electroencephalogram, maternal electromyogram and electrocardiogram. The averaging process also enhances small ECG components – typically the P and T waves, which may be completely submitted in the background noise. The program averages the signal point to point synchronized to the peak of the R wave. This requires a reliable detection of the QRS complex. For this purpose we applied an algorithm for detection of the fetal QRS complexes. This system has been described elsewhere [16]. Briefly it reliably recognizes QRS complexes based upon digital analysis of slope, amplitude and width. A digital bandpass filter composed of cascaded high-pass and low-pass filters reduces false detections caused by the various types of interference present in the ECG signal. This filter permits the use of low threshholds, thereby increasing detection sensitivity. The algorithm automatically adjusts threshholds and parameters periodically to adapt to such ECG changes as QRS morphology and heart rate. This adaptive approach enables accurate processing of ECG signals having diverse characteristics, QRS morphologies and heart rate changes. Figure 1a, b shows the signals obtained at the various steps in this digital signal processing. Once the peak of the R wave was defected, averaging of the whole ECG complex is performed synchronized to this point. Due to the variability of the R-T interval (even within short periods of time), such averaging synchronized to the R wave alone introduces a significant attenuation of the T wave amplitude. To overcome this problem a separate averaging of the T wave alone was carried, synchronized to its peak. The averaged T wave was then accurately aligned in time and position by a software routine to the rest of the QRS complex. The signal obtained following the averaging procedure is demonstrated in figure 2. Figure 3 shows peak detection.

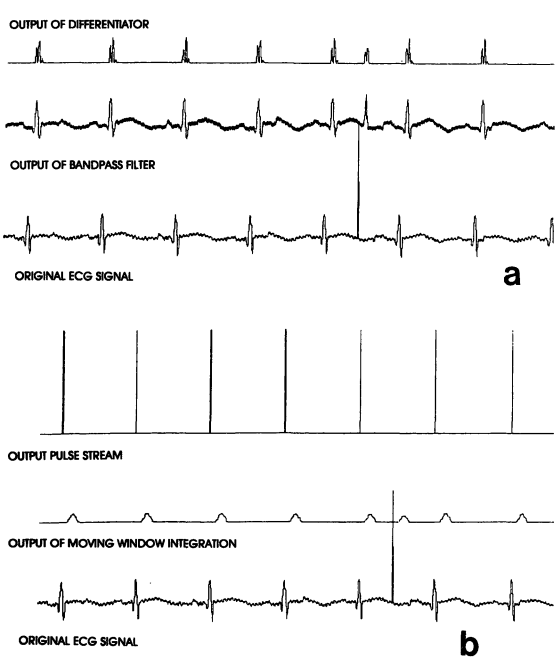

Figure 1. Steps in QRS detection algorithm:
a. the raw ECG signal is presented with the signals after the bandpass filter and differentiator.
b. the raw ECG signal is presented with the signals after moving window integration and QRS peak detection.

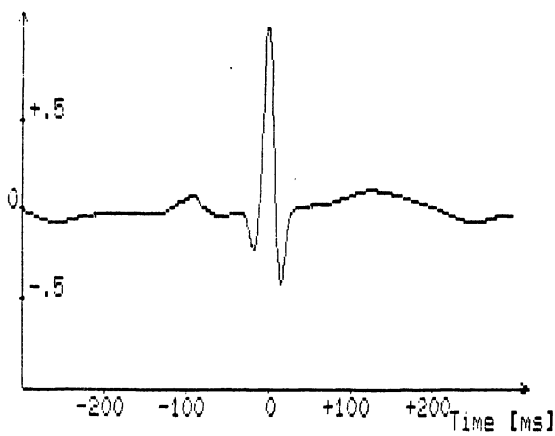

Figure 2. The ECG signal as printed by the computer after averaging synchronized to the peak of R and T waves.

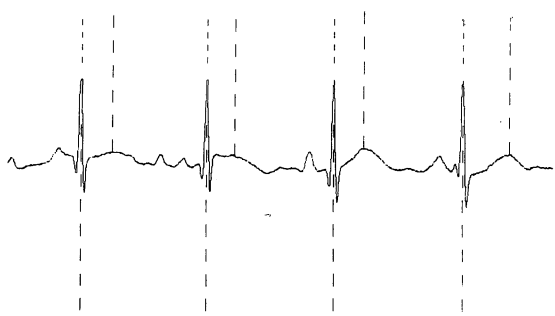

Figure 3. Software peak detection of R and T waves, before averaging.

2.2 Data analysis

The calculated components of the averaged ECG waveform, FHR, instantaneous and bandwidth variability are automatically transferred into an SPSS file for subsequent statistical analysis and display. Calculations were made based on the averaged FECG complex 30 sec preceding the UC, from the onset of UC to its peak, from the peak to the termination of the UC and 30 sec following the latter point. Specifically, the P-R interval, the ratio of the amplitude of the T wave to that of the QRS complex (T/QRS), and the ratio of the amplitude of the R wave to that of the S wave (R/S) were calculated. The cardiac axis was calculated according to SYMONDS [15]. Short term heart rate variability, or the instantaneous variability is defined here as the average of the absolute value of the instantaneous heart rate difference over the given time period. Long term variability is defined as the standard deviation of the instantaneous heart rate. The paired student t-test was applied for the statistical analysis of the data.

3 Results

All patients had spontaneous vaginal delivery. The range of 1 and 5 minute Apgar score was 8 and 10 respectively. Mean newborn weight was 3236 ± 387 gr. In all cases FHR patterns were within the normal range. In each patient 5 consecutive uterine contractions were recorded together with the FECG. The mean of the 5 measurements was then calculated and used as the representative value for the particular patient. In all, 125 uterine contractions were included. In one patient an episode of uterine tetany was recorded after the recording session described before was performed.

Table I lists the FHR parameters before, during and following UC. The instantaneous variability increased significantly during the first half of UC, from a mean of 3.9 bpm to 4.3 bpm. During the declining portion of the UC pressure, the latter value decreased to 4 bpm and returned to the precontraction value following its completion. A similar trend was observed in bandwidth variability (table I). No significant change was observed in the mean FHR itself, before, during or following the UC. Table II demonstrates 4 values related to the FECG signal. The P-R interval decreased slightly during the first part of UC. No significant change was observed in the R/S amplitude ratio. The cardiac axis rotated slightly from 114° to 112° during UC. The T/QRS ratio increased significantly during the first half of UC from a precontraction value of 0.18 to 0.26. During the second half of the UC it declined to 0.2 and subseuqently returned to the precontraction level. An episode of uterine tetany occured at 6 cm cervical dilation, which lasted for 100 seconds, then gradually declined to reach the baseline tone at 150 sec. The T/QRS ratio increased markedly from 0.2 to 2.4 at 120 seconds (table III). Instantaneous variability decreased from 3.9 to 1.5 at 90 seconds, then increased again. The FHR declined from 149 bpm to a trough of 68, then gradually increased again to 127 bpm at the completion of tetany.

Table I. FHR, instantaneous and bandwidth variability (bpm) before, during and following UC.

	Before UC	UC 1st half	UC 2nd half	After UC
Instantaneous variability	3.9 ± 0.17	4.3 ± 0.19*	4.0 ± 0.16	3.9 ± 0.2
Bandwidth variability	11.0 ± 0.45	12.3 ± 0.45*	11.5 ± 0.35	11.4 ± 0.5
FHR	141 ± 11	138 ± 14.6	139 ± 12.9	140 ± 14.7

* $p < 0.02$ * $p < 0.001$

Table II. Values of fetal ECG parameters before and during UC

	Before UC	During UC	(1st half)
P-R Interval (msec)	103 ± 1.6	101 ± 1.2	NS
R/S Amp ratio	2.45 ± 0.15	2.49 ± 0.16	NS
Cardiac axis	114°	112°	
T/QRS Ampratio	0.18 ± 0.02	0.26 ± 0.02	$p < 0.001$

Table III. FHR and ECG parameters during tetany

	Before tetany	30	60	90	120	150	180
T/QRS Amp ratio	0.2		1.8		2.4		0.9
STV (bpm)	3.9	2.9	2.7	1.5	2.2	3.5	–
FHR (bpm)	149	103	68	83	113	127	133

4 Discussion

This study demonstrates that during UC the most prominent change observed in the components of the FECG complex was an increase in T/QRS amplitude ratio. Elevation of T wave was described by PARDI [11] in association with variable and late acceleration during labor. Similar changes combined with ST segment elevation occured in fetal lambs during induced maternal hypoxia [13]. The concept of T/QRS ratio was introduced by the latter group. It was found that newborn infants with low Apgar scores had significantly elevated T/QRS ratio. Subsequently similar changes were demonstrated in the human fetus during acidosis [8]. The increase in T/QRS ratio in hypoxic fetal lambs was associated with elevated levels of circulating catecholamines [12]. Similar changes occured in the ST waveform, in spite of normal blood gas values, which were related to endogenous increase in plasma epinephrine.

Despite evidence which indicates that placental blood flow and transcutaneous Po_2 are reduced during UC [6], it is unlikely that the fetus is truely hypoxemic during this period. Even during moderate hypoxemia, myocardial metabolism remains aerobic, oxygen consumption and cardiac work remain unchanged and lactate continues to be consumed rather than produced [5]. It is conceivable that the changes we observed in the T/QRS ratio during UC are related to an increase in circulating catecholamines during UC. Such an increase was demonstrated in scalp samples and in umbilical arterial blood [9]. During hypoxia a marked increase in circulating catecholamines is observed both in the lamb [1] and the human fetus [9]. during uterine tetany, a marked decrease in placental blood flow ensues causing a fall in umbilical arterial Po_2 and a large rise in circulating catecholamines. This is reflected by the marked increase in T/QRS ratio, the decreased BTBV and the marked fetal bradycardia.

During normal labor the elevated T/QRS ratio was associated with increased FHR variability (both long and short term), during the 1st half of the UC. Increased variability in the human fetus is generally associated with periods of increased activity and breathing [18]. Paradoxically, acute mild to moderate hypoxia in the fetal lamb [3] causes an increase in FHR variability. Such an observation was recently made in the human fetus [17]. This may also be related to increased sympathoadrenal activity during UC, which may also be associated with mild reduction in arterial Po_2. With more profound changes, such as during uterine tetany, a marked decrease in heart rate variability was observed, associated with a marked increase in T/QRS ratio.

This study demonstrates the capability of the computer to process and enhance the FECG during labor while maintaining its various components undistored. The signal is derived from a scalp electrode, from which the the continuous FHR is also measured. In this manner two different variables are obtained without the need for additional transducers. The changes in the fetal ECG and heart rate variability during UC, considering the normal course of labor and its outcome, imply fetal health, and reflect the capacity of the fetus to respond to the stress of UC. Further studies are currently under way to investigate the components of the FECG during UC in the compromised fetus.

Abstract

This study was performed in order to investigate the fetal electrocardiogram (FECG) during uterine contractions associated with normal labor.

Twenty-five patients with low risk pregnancy between 38–41 weeks gestation were studied during the active stage of labor. Both FECG and intra-uterine pressure

are obtained in a conventional manner and are continually sampled into the computer. The FECG is averaged point-to-point, synchronized to the peak of the R-wave. This is performed by a QRS detection algorithm which is based on a digital analysis of slope, amplitude and width. A digital band-pass filter composed of cascaded high-pass and low-pass filters reduces false detections and permits the use of auto-adjustable low thresholds. A separate averaging is performed on the T-wave in order to prevent attenuation due to variable R-T interval. The T wave is subsequently alligned in time and position to the rest of the QRS complex. A significant increase was observed in the T/QRS amplitude ratio during the first half of the uterine contraction. Such an increase was also observed in the short and long-term FHR variability. No significant changes were observed in the other components of the FECG. In conclusion, by implementing a computer based system it is possible to analyse the FECG during labor. Based on this and previous studies it may well prove to be a sensitive indicator of fetal condition.

Keywords: Adaptive threshold, cardiac axis, digital filters, fetal ECG, heart rate variability, signal averaging, T/QRS ratio, uterine contractions.

Zusammenfassung

Interpretation des fetalen EKG unter der Geburt — der Einfluß der Uteruskontraktionen

Die Analyse des fetalen EKG kann eine wichtige Methode zur Überwachung des Feten unter der Geburt sein. Das Ziel dieser Untersuchung war die Erforschung der Reaktion des fetalen EKG (FECG) auf den Streß der Uterus-Kontraktionen (UK) unter normalen physiologischen Bedingungen.

Die Studie umfaßte 25 Patientinnen mit risikoarmer Schwangerschaft in der 38.—41. SSW. Die Aufzeichnungen des FEKGs stammen ausschließlich aus der Eröffnungsperiode. Das EKG-Signal wurde über eine konventionelle Spiral-Skalp-Elektrode aus rostfreiem Stahl abgeleitet, und der intrauterine Druck wurde mit Hilfe eines flüssigkeitsgefüllten, biegsamen Polyäthylen-Katheters gemessen. Beide Signale wurden aufgezeichnet und anschließend im Computer gespeichert.

Das fetale EKG, synchronisiert mit dem Maximum der R-Zacke, wird Punkt für Punkt gemittelt. Dieses Maximum wird mit einem QRS-Algorithmus, der auf der digitalen Analyse von Anstieg, Amplitude und Breite basiert, ermittelt. Ein digitaler Bandpaßfilter, bestehend aus hintereinandergeschalteten Hoch- und Tiefpaß-Filtern, reduziert die Anzahl falscher Erkennungen, die durch verschiedene Interferenzerscheinungen verursacht werden. Dieser Filter erlaubt den Gebrauch niedriger Schwellenwerte bei gleichzeitiger Erhöhung der Empfindlichkeit der Erkennung. Schwellenwerte und Parameter werden automatisch periodisch nachgeführt und an EKG-Veränderungen wie QRS-Morphologie und Herzfrequenz angepaßt. Für die T-Welle wird eine separate Mittelung durchgeführt, um eine Abschwächung, bedingt durch die sich verändernden RT-Intervalle, zu verhindern. Die T-Welle wird später bezüglich Zeit und Position zu dem Rest des QRS-Komplexes synchronisiert (Abb. 2). Abb. 3 zeigt die Ermittlung des Maximums.

Es wurden Berechnungen durchgeführt, die auf den R-R-Intervallen und dem gemittelten FEKG-Komplex 30 s vor bis zum Einsetzen der Uteruskontraktion, vom Beginn bis zum Gipfel, vom Gipfel bis zum Ende und in dem darauffolgenden 30 s-Abschnitt basierten. Die Kurzzeitschwankungen der Herzfrequenz, bezeichnet als instantane Herzfrequenz, wird in der vorliegenden Untersuchung als der Mittelwert der Absolutwerte der instantanen Herzfrequenzdifferenzen über eine vorgegebene Zeit verstanden.

Langzeitschwankungen werden definiert als Standardabweichung dieser instantanen Herzfrequenz.

Bei allen Patienten lag das FHF-Muster im Normalbereich. Alle Kinder wurden vaginal geboren. Das durchschnittliche Geburtsgewicht betrug 3.236 $\pm$ 387 g. Bei jeder Patientin wurden die Aufzeichnungen während 5 aufeinanderfolgender UK durchgeführt und diese 5 Messungen gemittelt. Ein signifikanter Anstieg sowohl der momentanen als auch der Langzeitschwankungen fand sich im ersten Teil der UK (Tab. I). Es fand sich keine signifikante Veränderung der FHF vor, während oder nach der UK. Während der ersten Hälfte der UK war bezüglich des T/QRS Amplituden-Verhältnisses ein signifikanter Anstieg zu verzeichnen (Tab. II). Bei einer Patientin wurde eine Aufzeichnung während einer Dauerkontraktion mit einer Dauer von 100 s durchgeführt. Das T/QRS-Verhältnis stieg deutlich an, während die Kurzzeitschwankungen und die FHF im gleichen Zeitraum abnahmen (Tab. III).

Ein Anstieg des T/QRS-Verhältnisses konnte bei tierexperimentellen Untersuchungen während fetaler Hypoxämie aufgezeigt werden. Ähnliche Veränderungen waren von erhöhten Catecholaminen-Werten begleitet. Seit gezeigt wurde, daß letztere im menschlichen Feten sich während der UK erhöhten, könnten sie als Auslöser (als möglicher Mechanismus) für die beobachteten Veränderungen angesehen werden. Die erhöhte FHF-Variabilität könnte ebenfalls eine erhöhte sympathoadrenale Aktivität widerspiegeln.

Zusammenfassend kann gesagt werden, daß durch die Einbindung eines computergestützten Systems die kontinuierliche Analyse des fetalen EKGs unter der Geburt

möglich ist. Ausgehend von vorausgegangenen Studien mag sich dies als sensitiver Indikator für den Zustand des Feten erweisen. Diese Untersuchung demonstriert, daß es selbst unter normalen physiologischen Bedingungen möglich ist, Veränderungen in den Komponenten des EKG-Komplexes aufzuspüren und zu quantifizieren.

Schlüsselwörter: Adaptive Schwelle, Digitalfilter, Fetales EKG, Herzachse, Herzfrequenzvariabilität, Signalmittelung, T/QRS-Verhältnis, Uteruskontraktionen.

Résumé

Interprétation de l'ECG fœtal au cours du travail. Effets des contractions utérines

L'analyse des modèles d'ECG fœtal peut être une méthode importante pour suivre le fœtus pendant le travail. Cette étude a été réalisée pour explorer la réponse de l'ECG fœtal (FECG) au stress des CU dans des conditions physiologiques normales. Vingt-et-une patientes avec des grossesses à bas risque entre 38 et 41 semaines de gestation ont été incluses dans l'étude: tous les enregistrements du FECG ont été effectués en phase active du travail. Le signal ECG a été obtenu à partir d'une électrode de scalp spiralée conventionelle en acier inoxydable et la pression intra-utérine a été mesurée à l'aide d'un catheter de polythène flexible rempli de liquide. Les deux signaux ont été enregistrés et dans un second temps entrés dans l'ordinateur.L'ECG fœtal est moyenné points par points synchronisés par le pic de l'onde R. Ce pic. est détecté à l'aide d'un algorythme de détection de QRS, algorythme qui est fondé sur une analyse digitale des pentes, amplitudes et profondeurs. Un filtre digital de bande passante composé d'une série de filtres réduit les fausses détections provoquées par les divers types d'interférence. Ce filtre permet l'utilisation de faibles seuils et de ce fait augmente la sensibilité de détection. Il ajuste automatiquement les seuils et les paramètres périodiquement pour les adapter aux modifications de l'ECG telles que la morphologie de QRS ou le rythme cardiaque.

Un moyennage à part est réalisé pour l'onde T afin d'éviter l'atténuation secondaire aux modifications de l'intervalle RT. Ensuite l'onde T est alignée en temps et en position sur le reste du complexe QES (figure 2). La figure 3 montre le pic de détection.

Les calculs sont effectués en se basant sur les intervalles R.R et les complexes de l'FECG moyennés les 30 secondes précédant la CU, du début de la CU jusqu'au sommet, du sommet à la fin de la CU, et pendant les 30 secondes suivant ce dernier point. La variabilité du rythme cardiaque à court terme qui désigne la variabilité instantanée est définie dans ce travail comme la moyenne de la valeur absolue la différence instantanée du rythme cardiaque sur la période donnée. La variabilité à long terme est définie comme la déviation standard de la fréquence cardiaque instantanée.

Chez toutes les patientes les modèles des RCF se situaient dans les valeurs normales. Toutes ont accouché par voie basse et le poids de naissance moyen des nouveaux-nés était de 3236 ∓ 387 gr. Pour chaque patiente l'enregistrement a été réalisé au cours de 5 contractions utérines consécutives et les 5 mesures ont été moyennées. On a trouvé une augmentation significative de la variabilité instantanée et en largeur de bande pendant la première partie de la CU (tableau I). Le rythme cardiaque fœtal ne se modifie pas significativement avant, pendant ni après la CU. On a observé une augmentation significative des ratios d'amplitude T/QRS au cours de la premuère moitié de la CU (tableau II). Chez une patiente on a effectué un enregistrement au cours d'un épisode de tétanie utérine, qui a duré 100 secondes. Le ratio T/QRS s'est élevé nettement alors que la variabilité à court terme et le RCF ont diminué au cours de la même période (tableau III).

Une augmentation du ratio T/QRS a été mise en évidence chez les animaux d'expérimentation au cours de l'hypoxie fœtale. Des modifications similaires sont accompagnées d'une augmentation des catécholamines. Puisque ces dernières ont été trouvées élevées chez le fœtus humain au cours de la CU, il s'agit d'un mécanisme possible pour les modifications observées. L'augmentation de la variablité du rythme cardiaque peut également refléter une activité médullosurénalienne augmentée.

En conclusion, il est possible d'analyser un continu l'ECG fœtal au cours du travail, en se servant d'un système fondé sur un ordinateur. En se basant sur les études antérieures, cette technique es tbien reconnue comme un indicateur sensible de la condition physique du fœtus. Cette étude démontre que même lors des conditions physiologiques normales, il est possible de détecter et de quantifier des modifications parmi les composantes des complexes de l'ECG.

Mots-clés: Axe cardiaque, contractions utérines, ECG fœtal, filtre digital, moyenage d'un signal, ratio T/QRS, genil adaptif, variabilité du rythme cardiaque.

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References

[1] ARTAL R, TH GLATZ, R LAM, PW NATHANIELSZ, CJ HOBEL: The effect of acute maternal hemorrhage on the release of cathecholamines in the pregnant ewe and the fetus. Am J Obstet Gynecol 135 (1979) 818

[2] CREMER M: Über die direkte Abteilung der Aktionsströme des menschlichen Herzens vom Ösophagus, und über das Elektrokardiogram des fotus. Münch med Wschr 53 (1906) 811

[3] DALTON KJ, GS DAWES, JE PARTICK: Diurnal, respiratory and other rhythms of fetal heart rate in lambs. Am J Obstet Gynecol 127 (1977) 414

[4] ENHORNING G, B WESTIN: Experimental studies of the human fetus in prolonged asphyxia. Acta Physiol Scand 31 (1954) 359

[5] FISHER D, MA HEYMANN, AM RUDOLPH: Fetal myocardial oxygen and carbohydrate consumption during acutely induced hypoxemia. Am J Physiol 242 (1982) 657

[6] HERBERT GM: Effects of uterine contractions. In: MOWAD AH, MD LINGHEIMER (eds): Uterine and placental blood flow. Masson publishing, New York 1982

[7] HIOKI T: Averaged fetal electrocardiogram obtained by direct lead in fetal distress diagnosed by fetal heart rate pattern. Acta Obstet Gynaecol Japonica 22 (1975) 162

[8] JENKINS HM, EM SYMONDS, DL KIRK, PR SMITH: Can fetal electrocardiogram improve the prediction of intrapartum fetal acidosis? Br J Obstet Gynaecol 93 (1986) 6

[9] LAGERCRANTZ H, P BISTOLETTI, L LUVELL: Catecholamine release in the human fetus and newborn infant. In: USDIN E, IJ KOPIN, J BARCHAS (eds): Catecholamines. Basic and clinical frontiers. Pergamon Press, Elmsford 1979

[10] MARVELL CJ, DL KIRK, HML JENKINS, EM SYMONDS: The normal condition of the fetal electrocardiogram during labor. Br J Obstet Gynaecol 87 (1980) 786

[11] PARDI G, E TUCCI, A UDERZO, D ZANINI: Fetal electrocardiogram changes in relation to fetal heart rate patterns during labor. Am J Obstet Gynecol 118 (1974) 243

[12] ROSEN KG, A DAGJARTSSON, BA HENRIKSSON, H LAGERCRANTZ, I KJELLMER: The relationship between circulating catecholamines and ST waveform in the fetal lamb electrocardiogram during hypoxia. A J Obstet Gynecol 149 (1984) 190

[13] ROSEN KG, I KJELLMER: Changes in the fetal heart rate and ECG during hypoxia. Acta Physiol Scand 93 (1975) 59

[14] SYMONDS EM: Configuration of the fetal electrocardiogram in relation to fetal acid-base balance and plasma electrolytes. J Obstet Gynecol Br Commonw 78 (1971) 957

[15] SYMONDS EM: Vectocardiography and acid-base balance in the human fetus. J Obstet Gynaecol Br Commonw 79 (1972) 416

[16] THALER I, I GOLDBERG, S ROTEM: A real time QRS defection algorithm and pattern analysis of the fetal ECG during labor. J Perinat Med 15 [Suppl. 1] (1987) 35

[17] THALER I, IE TIMOR-TRITSCH, Z BLUMENFELD: Effect of acute hypoxia on human fetal heart rate – the significance of increased heart rate variability. Acta Obstet Gynecol Scand 64 (1985) 47

[18] TIMOR-TRITSCH IE, I ZADOR, RH HERTZ, MG ROSEN: Human fetal respiratory arrhythmia. Am J Obstet Gynecol 127 (1977) 662

Israel Thaler, M. D.
Dept. of Obstetrics and
Gynecology "A"
Rambam Medical Center
Haifa, Israel

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